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Note on the Telegraphic Determination of the Longitude Greenwich—Ascension—Cape, in the Year 1908.

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It was decided by the Hydrographer to take advantage of the visit of H.M.S. "Mutine" to Ascension Island in the early part of this year to re-determine the longitude of that place both from Greenwich and the Cape, and incidentally to obtain a new value for the Greenwich-Cape longitude. Arrangements were made for Captain Monro and Lieutenant Gibson of the "Mutine" to attend at the Royal Observatory, Greenwich, in the autumn of 1907 before leaving England, and also on their return in 1908, for the purpose of ascertaining their personal equation referred to the standard observer with the transit circle. Mr. Pett, of the Cape Observatory, who was in England in 1907, was also directed to attend at Greenwich for the same purpose. The arrangement for the work was left to me; and when the Eastern Telegraph Company, at the Hydrographer's request, kindly placed the use of their cable at our disposal, I arranged with Mr. Judd, Electrician-in-chief of the Company, and his assistant, Mr. Young, as to the method of signalling, etc., the essential points being that the syphon recorders of the Company at the several places should be used as chronographs, and that the signals should be transmitted without the interposition of relays. As the result of experiment, it was found impracticable to use one syphon only to record both the clock signals and the out-going or in-coming signals; and at each place, therefore, a second syphon was added to the recorders, making two parallel lines on the running tapes. At Ascension this second syphon was actuated by the chronometer, and at Cape Town and Porthcurno by the clocks at the Cape and Greenwich Observatories respectively. The Post Office authorities kindly granted the use of their wires between Greenwich and Porthcurno; and when signals were exchanged, these were joined up without relays, to make an unbroken line.

The circuit from the sidereal standard relay at Greenwich actuated a telegraphic sending apparatus, and a current was transmitted which recorded the seconds of the Greenwich clock on a tape chronograph at the Observatory, and also actuated the second syphon at Porthcurno, these two being synchronous except for the time of transmission from Greenwich to Porthcurno, which was only $0^{s}{\cdot}006$. This quantity was found by sending return signals immediately after the exchange through the cable from Porthcurno to Greenwich, which were recorded on the syphon recorder and also on the chronograph at Greenwich. A very similar arrangement was made at the Cape, where the time of transmission was found inappreciable.

It is essential that if both the syphons of a recorder are actuated at the same instant, the deflections on the tape in the two lines should be exactly abreast one another; and if they are not, the distance between them must be ascertained and allowed for. This difference of position between the syphons is called "parallax."

For the signals which were sent between Ascension and Porthcurno, the ends of the cables both at Madeira and St. Vincent, the two intermediate stations, were joined up. Similarly, when signals were sent between Ascension and Cape Town, the cables were joined at St. Helena, so that no intermediate relays were introduced, and signals were satisfactorily received through both these lengths of cable, distances of 4213 and 2687 nautical miles respectively.

The instrument used at Ascension for the determination of time was a reversible transit (D), one of the series of five originally made for the Transit of Venus expedition of 1874, and subsequently modified for use in various longitude determinations from 1888 to 1902. It was last used in the determination of the Greenwich-Paris longitude 1902, and had since then been fitted with the central illumination designed by Mr. Harold Christie and myself, and described in the *Monthly Notices of the R.A.S.*, 1908, January.

The Chronograph used for recording the times of the observations at Ascension, and also at Greenwich while ascertaining personal equation, was a small field chronograph made by Lindqvist. The tape is driven by clockwork, the speed of which can be regulated within certain limits. The clock and tapper records are made with needle points so fitted to the ends of levers that after striking the tape vertically they will rock against the push of a light spring in a direction parallel to the motion of the tape, and by this means the point is withdrawn from the paper without tearing it, though this, of course, would only occur in case of the lever not rising immediately after striking.

The Chronometer used at Ascension was a quick train chronometer by Pennington, and fitted by Lindqvist for use in connection with the field chronograph. An extra wheel is fitted on to the arbor of the seconds hand, on the outer edge of which are 60 teeth. An agate point on the spring contact is pressed forward by these teeth, and remains there during the period of one beat. As the wheel revolves, the agate point slips back into the notch following, and thus breaks the contact. The teeth of the wheel are cut so that one contact is made at each second except the 60^s, and an extra contact just after the 30^s.

Captain Monro proceeded to Greenwich in 1907 September, and was shortly followed by Lieutenant Gibson, for instruction in the use of the instrument under Mr. Hollis, and to ascertain personal equation, remaining there three or four weeks. Observations for personal equation, with the same instrument as was used at Ascension, were made by Captain Monro on 9 nights and by Lieutenant Gibson on 4 nights.

The "Mutine" arrived at Ascension on January 20, and a site was at once selected for the instrument. This was on the rising ground at New Krutown, between the ends of the two Northern

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buildings. From the Observation Pillar at the settlement it bore S. 34° 17′ 43″ W. distant 1524 feet. This position was selected with a view to obtaining a clearer South and Zenith sky clear of the line of cloud which at times streams away to leeward from the summit of the island. A meridian mark was erected at a little over half a mile to the southward on the sky line.

Observations were begun on the night of January 26, and continued nightly by one or both observers until February 28, excepting only 3 nights when clouds prevented. Signals were exchanged with both the Cape and Porthcurno on the nights of February 1, 2, 8, 9, 16, 22, and 23, and on the 15th with the Cape only, the land line between Greenwich and Porthcurno having broken down on that night.

Captain C. H. Simpson, R.N., was appointed to superintend the signalling operations at Greenwich. He also read all the signal tapes from each of the stations. The signals for comparison of clocks were sent from Porthcurno, Ascension, and Cape Town by means of the ordinary apparatus used by the Cable Company for the transmission of messages, by hand, at intervals of 10 seconds for periods of about 3 minutes, giving approximately 20 signals to each set. The time of transmission between Porthcurno and Ascension was found to be $0^s \cdot 529$, while that between Ascension and Cape Town was $0^s \cdot 250$.

On the return of the "Mutine" to England in 1908 July, Captain Monro and Lieutenant Gibson made a further determination of personal equation at Greenwich, observations being obtained on 8 nights by each observer.

The programme of observations at Ascension on each night consisted generally of the observation of 16 clock stars by each observer, symmetrically arranged with respect to the two positions of the instrument, micrometer east and west, and a sufficient number of stars of greater declination both north and south for the determination of azimuth error, together with an adequate determination of level. The two observers at Ascension observed groups of stars alternately, and the order of micrometer east and west was usually reversed on alternate nights.

The methods of determining constants of the instruments and instrumental errors were essentially the same as those described in the Greenwich publication, "Determinations of Longitude, 1888–1902." The equatorial intervals of the vertical wires were determined first at Greenwich and afterwards at Ascension by means of the transits of a large number of clock stars, 100 in the first case, and 240 in the second, observed over all nine wires. The collimation error used in the reduction was determined by the observations of the nadir which were made at the beginning and end of each night's work, but this error is finally determined by the reversal of the instrument.

During the observations for personal equation at Greenwich in 1907 there was no sensible discordance between the clock errors found in the two positions of the instrument, but at Ascension and at Greenwich in 1908 July a difference was found of about $0^s{\cdot}25$ by both observers, and it would seem, therefore, that some change must have taken place in the instrument in transit from Greenwich to Ascension. Inequality of pivots might account for this difference; but if this existed, the level error determined in the two positions of the instrument would show a similar disagreement. The observations of level, however, made during the longitude operations, and also some special series made in 1908 September at Greenwich, show a difference in West − East of only about $+0''{\cdot}35$ in the mean, which would cause a difference of clock error W. − E. not greater than $0^s{\cdot}04$, and would not therefore account for the discordance observed. It seems therefore reasonable to treat the difference purely as an error in the determination of collimation. It is possible that it might be due to some error in the adjustment of the Bohnenberger eyepiece used in the determination of collimation by the nadir in reversed positions of the instrument. Experiments were made at Greenwich to test this, but the collimation errors determined by observation of a south mark and nadir by reversal in both cases were in agreement.

On the other hand, the polar stars observed at Greenwich in 1908 in reversed positions of the instrument agree with the clock stars in the collimation error which they indicate. In any case it may be taken that the error is eliminated by taking the mean for the two positions of the instrument.

Level Error was determined by the striding level and by observation of the nadir. In the determination with the striding level, the micrometer screw was used so as to eliminate as far as possible any differences of scale value in different parts of the tube. The difference of level error as ascertained by the striding level and nadir for the nights on which exchanges of signals were made amounts in the mean to $0^s{\cdot}014$.

The Azimuth Error.—The value of "*n*" adopted each night was deduced from usually four observations with the micrometer E and a similar number micrometer W. The stars for this purpose used at Ascension were generally at some distance from both North and South poles, owing to the latitude of the place being small, but for this reason also the correction introduced by the azimuth error is exceedingly small, as the clock stars used were all near the zenith.

The adopted error of the Sidereal Standard clock at Greenwich is the weighted mean of errors, corrected for personal equation referred to the standard observer, found by the various observers with the Transit Circle, and the rates used are those deduced from these errors.

The adopted clock error at the Cape is that obtained by Mr. Pett using the non-reversible Transit Circle at the Cape, these errors and adopted rates having been supplied by H.M. Astronomer at that place.

The differences of longitude of Greenwich—Ascension and Cape—Ascension have been calculated, using the errors obtained by each observer at Ascension independently. Rates of the chronometer were calculated from the observations obtained by each observer, and

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from these and from the rates obtained both from the Greenwich and Cape clocks by comparison of signals the adopted rates were deduced.

The following Table I. shows the difference of the error of the Sidereal Standard at Greenwich as found by Captain Monro and Lieutenant Gibson, and the corresponding adopted error found by the standard observer with the Greenwich Transit Circle, the errors by the longitude observers being reduced to the Greenwich meridian. Table II. shows the error found by Mr. Pett observing with the Greenwich Transit Circle, compared with the standard observer. Table III. gives the difference of longitude found by each observer on each night, the error of the chronometer at Ascension being compared with the adopted error of the Sidereal Standard at Greenwich as found by the standard observer and with the error of the Standard clock at the Cape Observatory as found by Mr. Pett, the personal equation in the preceding tables being applied.

TABLE I.

Table of Personal Equations of Captain Monro and Lieutenant Gibson, using Transit D, compared with the Standard Observer with the Transit Circle as found at Greenwich 1907 *and* 1908.

Captain Monro.				Lieutenant Gibson.			
Date. 1907.	Personal Equation. Transit Circle with Annular Illumination.	Date. 1908.	Personal Equation. Transit Circle with Central Illumination.	Date. 1907.	Personal Equation. Transit Circle with Annular Illumination.	Date. 1908.	Personal Equation. Transit Circle with Central Illumination
	s		s		s		s
Sep. 18	+0·28	Jul. 14	+0·42	Oct. 2	+0·34	Jul. 20	+0·24
19	·16	20	·21	4	·19	21	·35
23	·26	22	·18	7	·20	22	·21
24	·33	23	·19	8	·32	23	·00
30	·42	24	·21		+0·263	24	·01
Oct. 2	·31	27	·22			27	·22
4	·21	29	·25			29	·24
7	·27	Aug. 7	·29			Aug. 7	·14
8	·35		+0·246				+0·176
	+0·288	Correction to reduce to annular illumination.	+·056			Correction to reduce to annular illumination.	+·056
			+0·302				+0·232

Adopted +0^{s}·295 Adopted +0^{s}·248

The central illumination of the Greenwich Transit Circle was fitted in 1908 April, after the observations at Ascension in connection with the longitude determination were completed, the annular illumination being in use at that time. The above correction (0^{s}·056) calculated from 31 comparisons made with the two methods of illumination between April 30 and September 26 has therefore been applied.

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Table II.

Table of Personal Equation of Mr. Pett, compared with the Standard Observer, both observing with the Transit Circle at Greenwich in 1907.

Date.	Personal Equation.	Date.	Personal Equation.
	s		s
Sept. 16	+0·09	Sept. 24	–0·02
17	+ ·01	26	– ·01
18	+ ·05	27	+ ·02
19	+ ·00	Oct. 2	+ ·03
20	+ ·01	4	+ ·06
23	– ·06	Adopted	+0·02

Note.—In the above tables a + sign means that the quantity is to be added to the "clock slow" found by the observer to find "clock slow" by the standard observer.

Table III.

Difference of Longitude: Greenwich—Ascension—Cape.

Final Results.

Date. 1908.	Difference of Longitude by M.	Divergence from Mean.	Difference of Longitude by G.	Divergence from Mean.	Time of Transmission.
	Greenwich—Ascension.		Greenwich—Ascension.		
	h m s	s	h m s	s	s
Feb. 1	0 57 40·492	+0·094	0 57 40·476	+0·122	+0·545
2	·355	– ·043	·285	– ·069	+ ·519
8	·249	– ·149	·239	– ·115	+ ·518
9	·367	– ·031	·275	– ·079	+ ·528
16	·462	+ ·064	·404	+ ·050	+ ·536
22	·496	+ ·098	·430	+ ·076	+ ·537
23	·368	– ·030	·372	+ ·018	+ ·519
	0 57 40·398	±0·073	0 57 40·354	±0·076	+0·529
	Cape—Ascension.		Cape—Ascension.		
	h m s	s	h m s	s	s
Feb. 1	2 11 34·994	–0·039	2 11 34·978	–0·006	+0·251
2	·998	– ·035	·928	– ·056	+ ·258
8	35·035	+ ·002	35·025	+ ·041	+ ·256
9	·032	– ·001	34·940	– ·044	+ ·252
15	·071	+ ·038	·993	+ ·009	+ ·236
16	·082	+ ·049	35·024	+ ·040	+ ·251
16	·066	+ ·033	·008	+ ·024	+ ·249
22	·030	– ·003	34·964	– ·020	+ ·253
23	34·993	– ·040	·997	+ ·013	+ ·246
	2 11 35·033	±0·027	2 11 34·984	±0·028	+0·250

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By subtracting the values of the longitude determined night by night (Cape—Ascension)—(Greenwich—Ascension) values are obtained of the difference of longitude between Greenwich and the Cape independently of the error of the chronometer found at Ascension. The following is a series of values so found from the above results. For Feb. 16 the result from the first exchange of signals Cape—Ascension has a'one been used, as that exchange more closely followed the exchange between Greenwich and Ascension.

Greenwich—Cape.

	h m s	s
Feb. 1	1 13 54·502	−0·123
2	·643	+ ·018
8	·786	+ ·161
9	·665	+ ·040
16	·620	− ·005
22	·534	− ·091
23	·625	·000
	1 13 54·625	±0·063

From the foregoing it will be seen that the results, so far as they can be at present determined, and adopting the mean of the two observers at Ascension, are as follows:—

	h m s	s
Greenwich—Ascension	0 57 40·37	±0·025
Cape—Ascension	2 11 34·99	±0·008
Greenwich—Cape	1 13 54·62	±0·022

The probable errors here given are deduced solely from the divergences in these last three tables.

The longitude of the Cape hitherto adopted is 1^{h} 13^{m} $54^{s}{\cdot}76$ E, from which the above result differs but little.

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